Photo-assisted negative ion production in cesium sputter ion source

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INTRODUCTION

The negative ion formation in the Source of Negative Ions by Cesium Sputtering (SNICS) [1] occurs on the surface of a cathode or "target" containing the ionized material, exposed to cesium ion (Cs+) bombardment [2]. Vogel recently introduced a hypothesis that the negative ion current can be enhanced by exposing the cathode to a laser beam resonantly exciting neutral cesium atoms to 7p electronic states, which acts as a catalyst for negative ion production via so-called ion pair production [3]. Recently we reported [4] that the photo-assisted production of negative ions can be provoked by laser at various wavelengths with the photon energy exceeding a certain threshold, which questioned the resonant ion pair production hypothesis. Here, we present new data at resonance and off-resonance wavelengths for neutral Cs excitation. The data excludes the contribution by ion pair production on the negative ion current enhancement. We propose a mechanism to explain the photo-assisted negative ion production.

EXPERIMENTAL METHODS

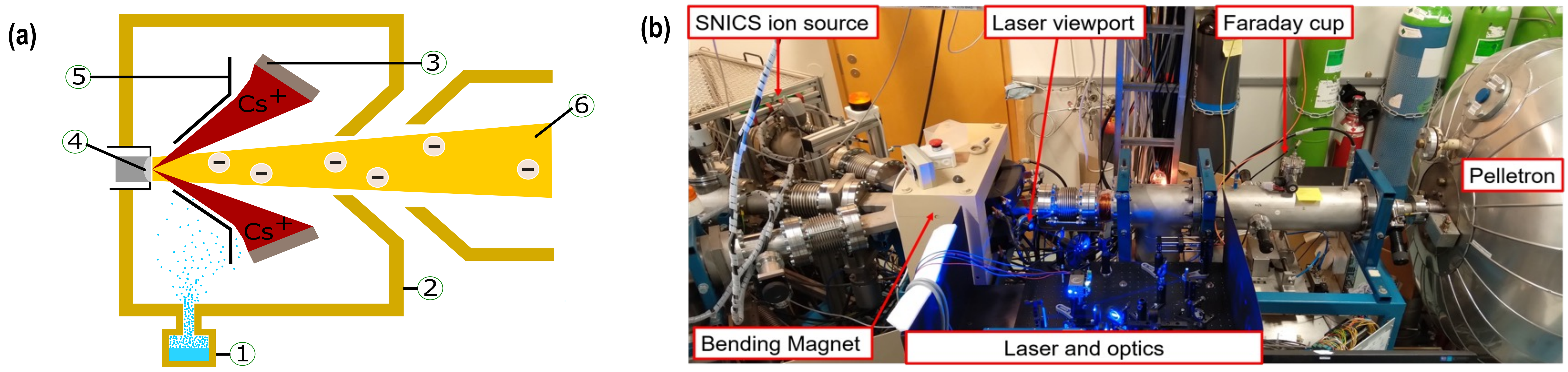

Figure 1. (a) Schematic drawing of the SNICS ion source. (1) Cesium oven and transfer line, (2) ionization chamber, (3) ionizer, (4) cathode, (5) focusing electrode (immersion lens) and (6) extraction channel and electrodes. (b) The experimental setup at JYFL accelerator laboratory. The laser beam was focused to the SNICS cathode through the viewport of the bending magnet. [5]

RESULTS

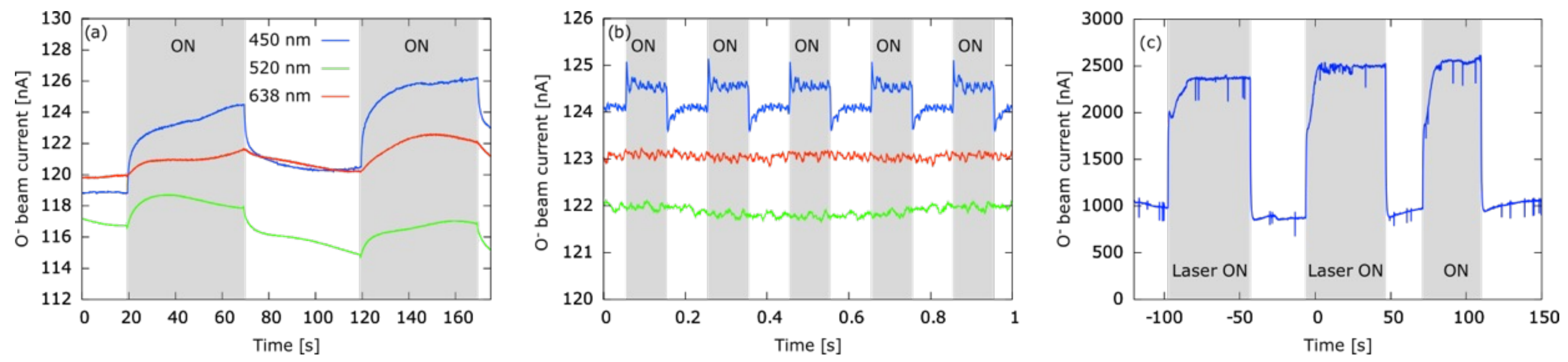

Figure. 2. The effect of (a) 50 s and (b) 100 ms laser pulses at 450 nm / 1.6 W, 520 nm / 1.0 W and 638 nm / 0.7 W wavelengths / powers on the O^- beam current. Example of the 445 nm, high power 6 W laser on the O^- beam current is presented in (c). [2]

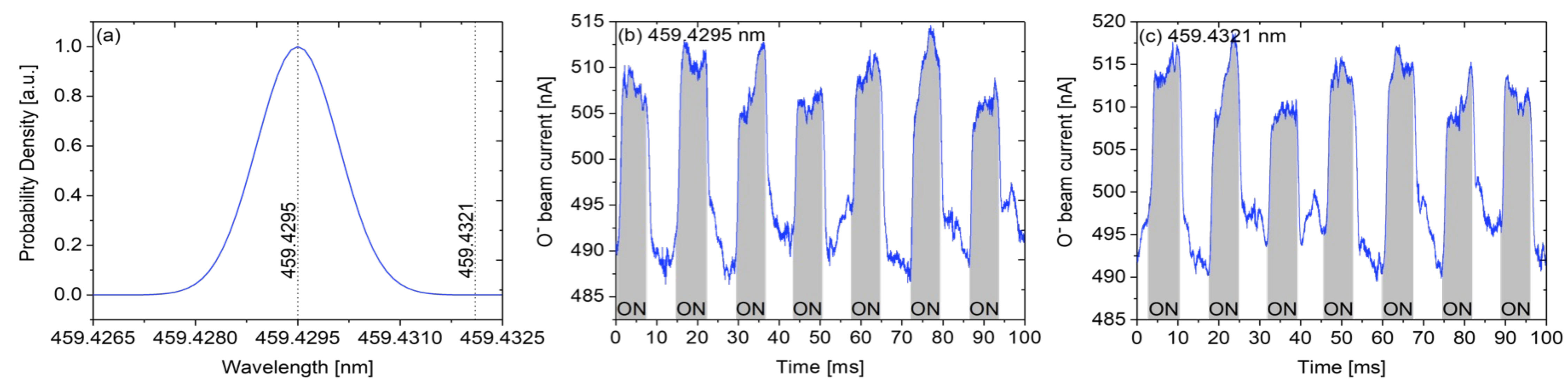

Figure. 3. Probing the resonance of the excitation of the $7p_{1/2}$ electronic state of neutral Cs. (a) shows the laser wavelengths used for probing the putative ion pair production. The prompt effect of the laser exposure on the O− beam current with different wavelengths: (b) in-vacuum resonance at 459.4295 nm and (c) 459.4321 nm, being outside the maximum Doppler broadening. [5]

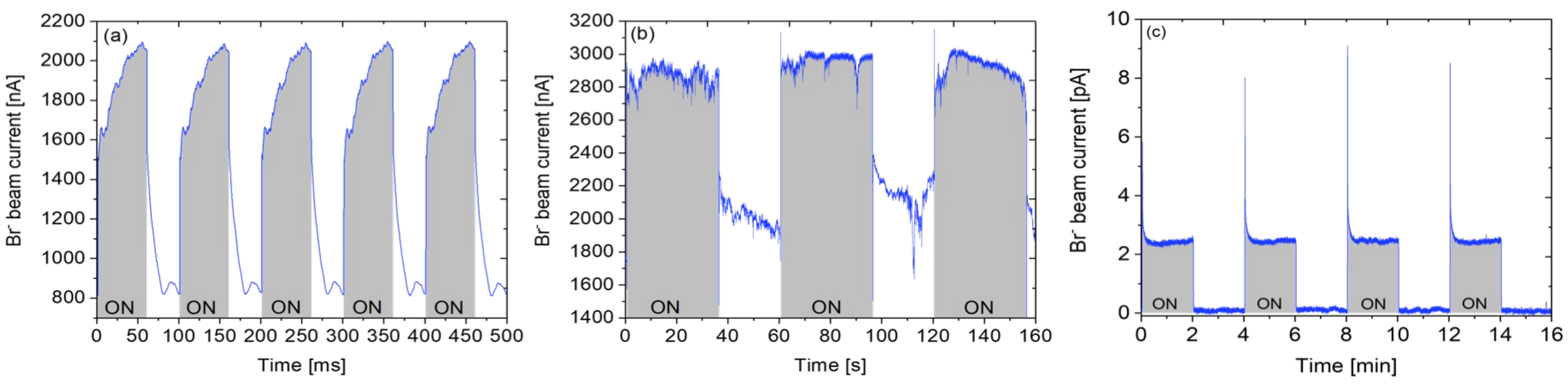

Figure. 4. The effect on the Br− beam current with (a) 17 A ionizer current and 3.6 W laser output power, (b) 16 A ionizer current and 4.7 W laser output power, (c) Cs oven OFF with 5.5 A ionizer current and 5.2 W laser output power. [5]

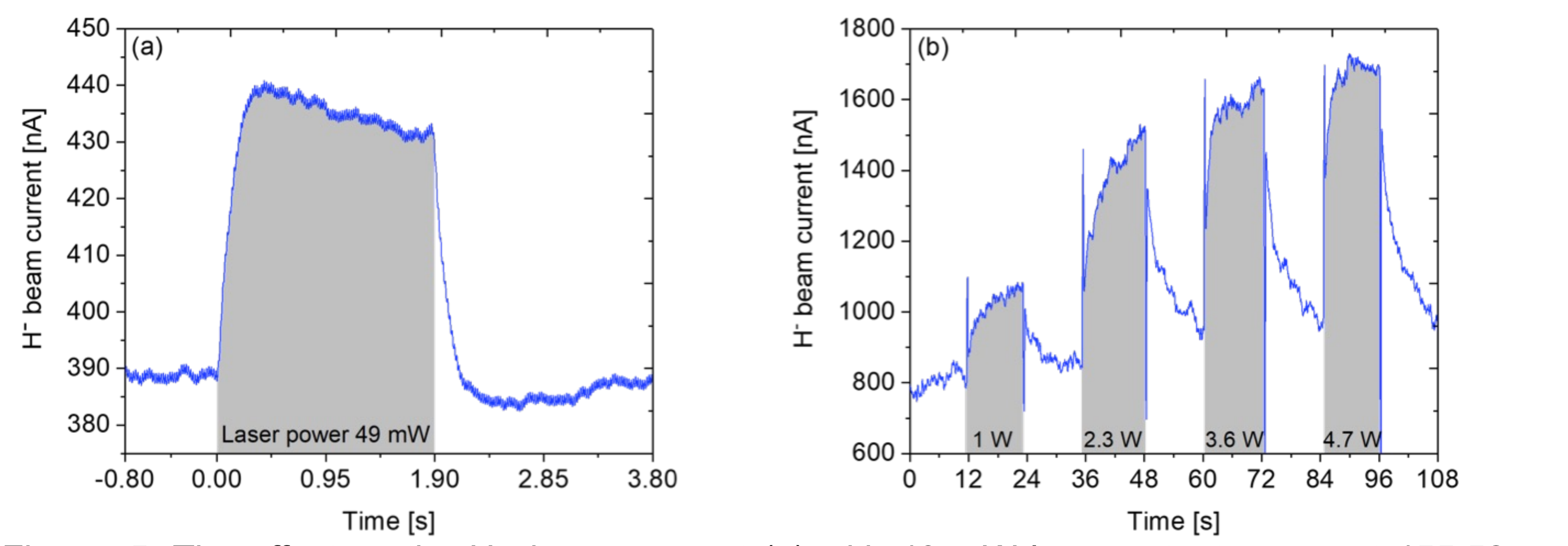

Figure. 5. The effect on the H− beam current (a) with 49 mW laser output power at 455.52 nm wavelength and (b) the effect with different laser output power on the H− beam current. The laser pulse length is 1.90 s in (a) and 12 s in (b), both having a 50% duty factor. [5]

PROPOSED MECHANISM

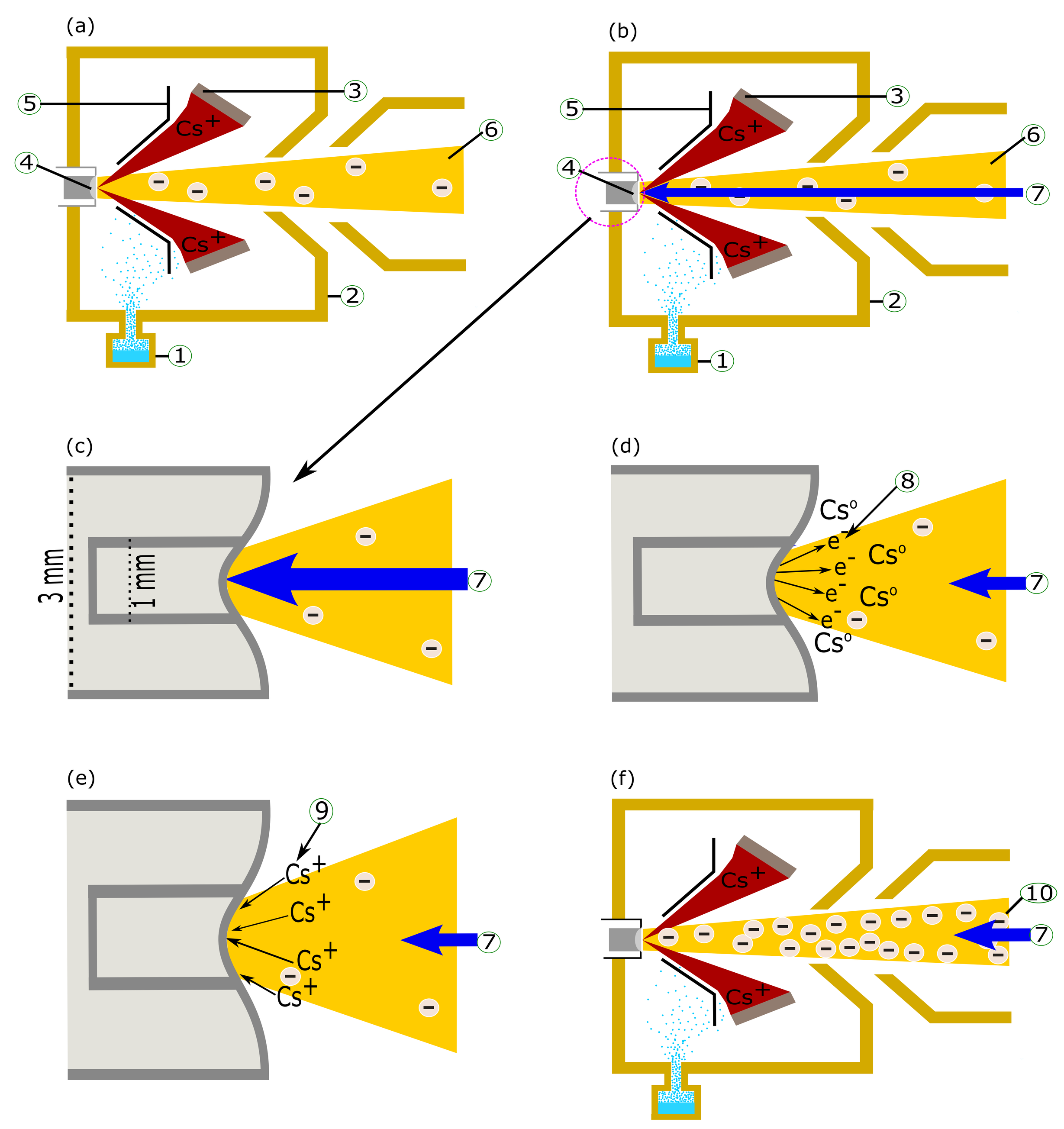

Figure. 6. A schematic drawing of the SNICS ion source (a) and the illustration of the proposed photo-assisted negative ion production mechanism (b)-(f). The applied laser beam (c) induces photoelectron emission from the cathode (d) resulting in volumetric ionization of the Cs vapor (e). The enhanced Cs+ bombardment of the cathode increases the negative ion yield, i.e. the beam current in (f) is higher than the original beam current in (a). The labeling refers to the following: (1) cesium oven and transfer line, (2) ionization chamber, (3) ionizer, (4) cathode, (5) focusing electrode (immersion lens), (6) extraction channel and electrodes, (7) laser beam, (8) emitted photoelectrons, (9) ionized Cs+ and (10) increased negative ion yield. [5]

CONCLUSIONS

- **Beam current enhancement depends on the applied laser power, wavelength, pulse length and the ion source conditions.**
- **The extracted beam current can be enhanced by a factor > 2.**
- **Resonant ion pair production does not play a role on the beam current enhancement.**
- **One can produce negative ion beam even without hot filament (ionizer) when the target contains alkali metal compound.**
- **We present a qualitative explanation for the observed effect.**

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